

# **Richard W. Hamming**

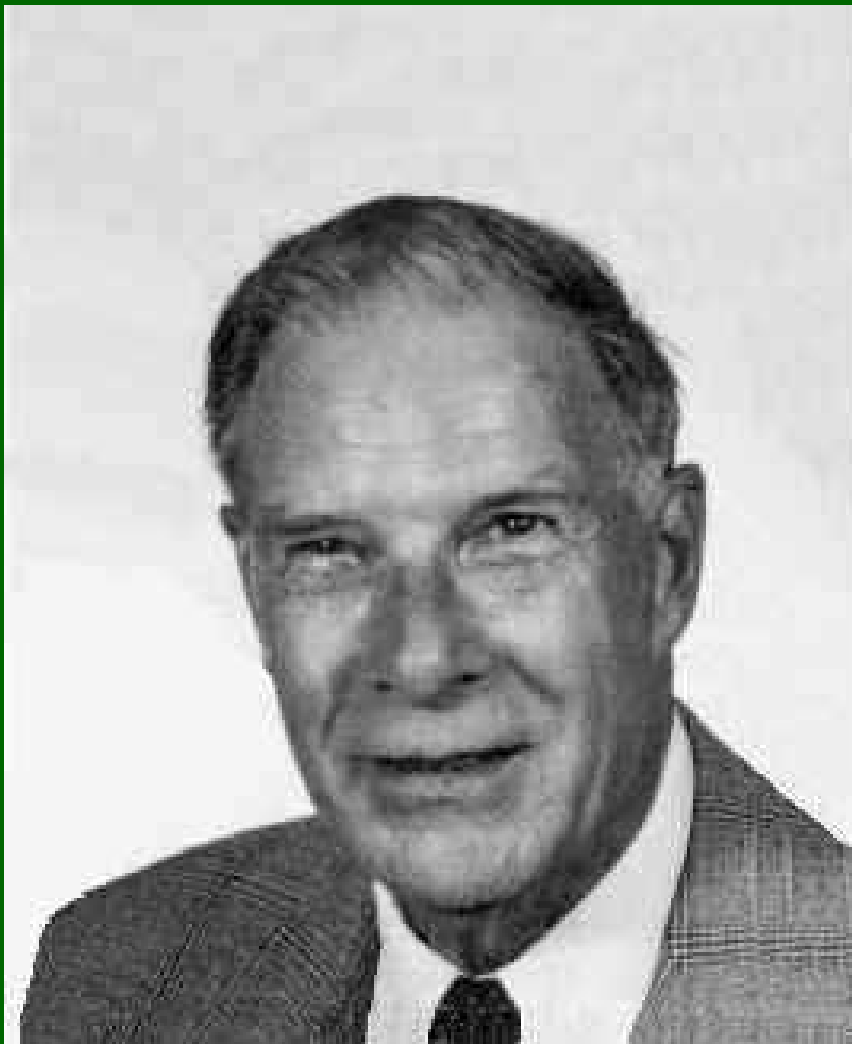


## **Learning to Learn**

The Art of Doing Science and Engineering

## **Superintendent's Guest Lecture**

**30 April 1990**





# **Editorial note**

**Dr. Hamming's Superintendent's Guest Lecture (SGL) presentation is an excellent summary of the many diverse, challenging ideas tackled in his book and course.**

**These slides summarize Dr Hamming's background, contributions, awards and publications as listed in his curriculum vita.**



# **Richard W. Hamming**

**Born: 11 Feb 1915 in Chicago Illinois USA**

**Died: 7 Jan 1998 in Monterey California  
USA**

## **Degrees Received**

- 1942, Ph.D., Mathematics, University of Illinois
- 1939, M.A., Mathematics, University of Nebraska
- 1937, B.S., Mathematics, University of Chicago

# Richard W. Hamming



## Work Experience

- 1945-46 Los Alamos Lab, Manhattan Project
  - *Atomic Bomb Numerical Calculation Research*
- 1946-1976 Bell Laboratories
  - *Mathematics and computing as applied to military and telephone research*
  - *Adjunct Professor of Statistics, Princeton, 3 years*
- 1976-1998, Naval Postgraduate School, Professor

# Richard W. Hamming



## Honors

- President, Association Computing Machinery
- Turing Prize of ACM
- Fellow IEEE
- Piore Prize, 1979
- National Academy of Engineering, 1980
- Pender Prize, 1981

# Richard W. Hamming



## Honors

- IEEE R. W. Hamming Gold Medal namesake
  - *First recipient, \$10,000 prize, 1996*
  - *“For exceptional contributions to information sciences and systems”*
- Vice President, Math Section, American Association for the Advancement of Science (AAAS)
- Editor of numerous journals

# Quotable quotes

## 1



**The purpose of computing is insight,  
not numbers.**

**It is better to do the right problem  
the wrong way, than the wrong  
problem the right way.**



# Quotable quotes

## 2



**Mathematics is the language of clear thinking.**

**If the prediction that an airplane can stay up depends on the difference between Riemann and Lebesgue integration, then I don't want to fly in it.**

# Quotable quotes

## 3



**Mathematics is an interesting intellectual sport but it should not be allowed to stand in the way of obtaining sensible information about physical processes.**

- Quoted in N. Rose *Mathematical Maxims and Minims* (Raleigh NC 1988).

# Quotable quotes

## 4



**I bugged Claude Shannon for years and years to write a book on Information Theory so that everyone would understand it. He refused, so I went ahead & wrote it.**

**A good theoretician can account for almost any result that is produced, right or wrong.**

# Quotable quotes

## 5



**My doctoral dissertation was 27 pages long.**

- *Some Problems in the Boundary Value Theory of Linear Differential Equations*
- *University of Illinois at Urbana-Champaign, 1942*

***[“... uhh, why so short, Dr. Hamming??”]***

**There was a lot less to know in 1942.**

- *see chapter 1, exponential growth of knowledge*

# Quotable quotes

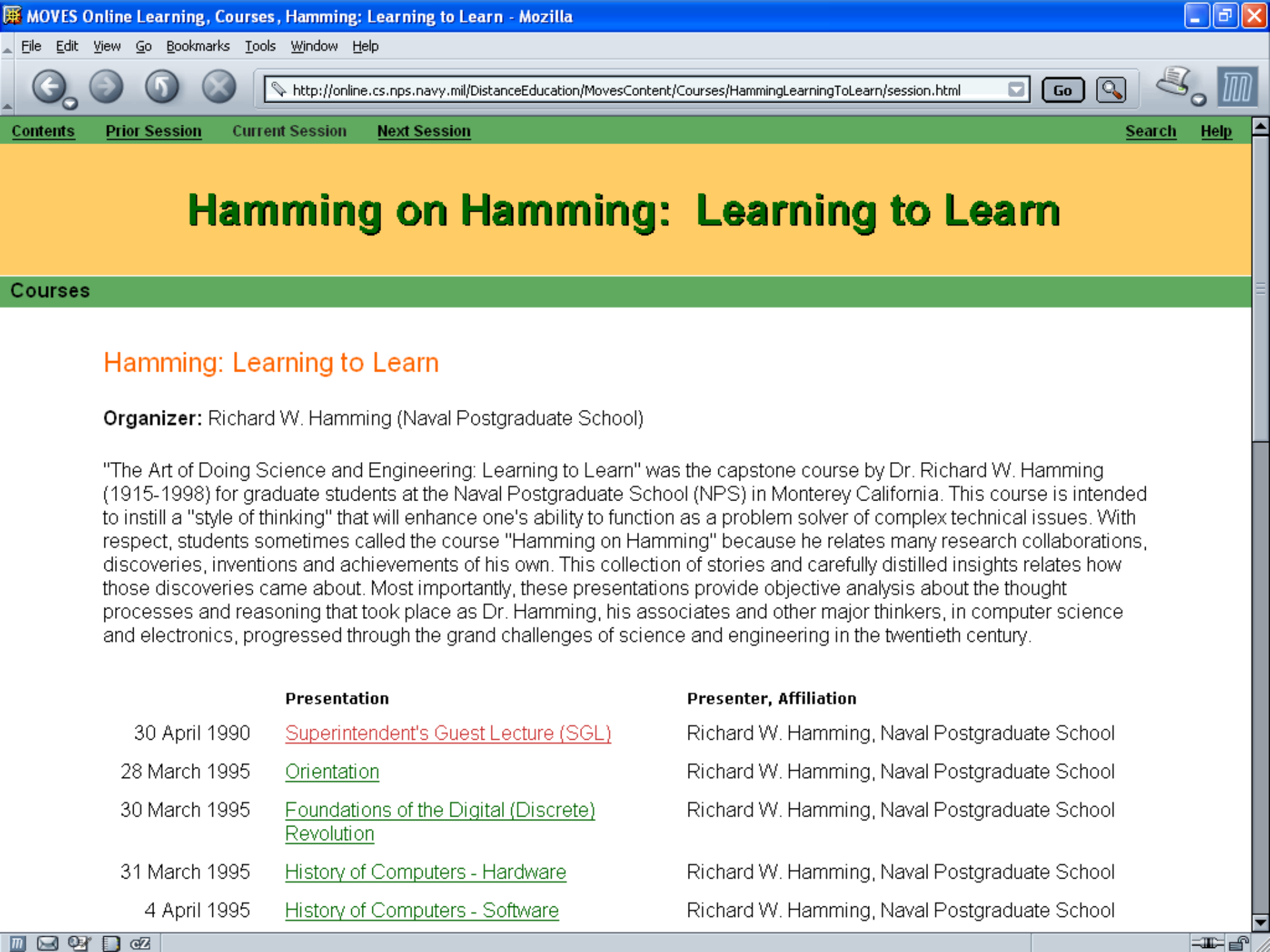
## 6



**If you don't work on important problems, it's not likely that you'll do important work.**

**Usually expressed as a thought-provoking challenge to the audience:**

- Who here wants to do important work in their career?
- Who here is working on important problems?
- (for those not raising a hand) Why not?



# Hamming on Hamming: Learning to Learn

## Courses

### Hamming: Learning to Learn

**Organizer:** Richard W. Hamming (Naval Postgraduate School)

"The Art of Doing Science and Engineering: Learning to Learn" was the capstone course by Dr. Richard W. Hamming (1915-1998) for graduate students at the Naval Postgraduate School (NPS) in Monterey California. This course is intended to instill a "style of thinking" that will enhance one's ability to function as a problem solver of complex technical issues. With respect, students sometimes called the course "Hamming on Hamming" because he relates many research collaborations, discoveries, inventions and achievements of his own. This collection of stories and carefully distilled insights relates how those discoveries came about. Most importantly, these presentations provide objective analysis about the thought processes and reasoning that took place as Dr. Hamming, his associates and other major thinkers, in computer science and electronics, progressed through the grand challenges of science and engineering in the twentieth century.

#### Presentation

#### Presenter, Affiliation

30 April 1990	<a href="#">Superintendent's Guest Lecture (SGL)</a>	Richard W. Hamming, Naval Postgraduate School
28 March 1995	<a href="#">Orientation</a>	Richard W. Hamming, Naval Postgraduate School
30 March 1995	<a href="#">Foundations of the Digital (Discrete) Revolution</a>	Richard W. Hamming, Naval Postgraduate School
31 March 1995	<a href="#">History of Computers - Hardware</a>	Richard W. Hamming, Naval Postgraduate School
4 April 1995	<a href="#">History of Computers - Software</a>	Richard W. Hamming, Naval Postgraduate School

28 March 1995	<a href="#">Orientation</a>	Richard W. Hamming, Naval Postgraduate School
30 March 1995	<a href="#">Foundations of the Digital (Discrete) Revolution</a>	Richard W. Hamming, Naval Postgraduate School
31 March 1995	<a href="#">History of Computers - Hardware</a>	Richard W. Hamming, Naval Postgraduate School
4 April 1995	<a href="#">History of Computers - Software</a>	Richard W. Hamming, Naval Postgraduate School
6 April 1995	<a href="#">History of Computer Applications</a>	Richard W. Hamming, Naval Postgraduate School
7 April 1995	<a href="#">Artificial Intelligence (AI) - I</a>	Richard W. Hamming, Naval Postgraduate School
11 April 1995	<a href="#">Artificial Intelligence (AI) - II</a>	Richard W. Hamming, Naval Postgraduate School
13 April 1995	<a href="#">Artificial Intelligence (AI) - III</a>	Richard W. Hamming, Naval Postgraduate School
14 April 1995	<a href="#">n-Dimensional Space</a>	Richard W. Hamming, Naval Postgraduate School
18 April 1995	<a href="#">Coding Theory - I</a>	Richard W. Hamming, Naval Postgraduate School
20 April 1995	<a href="#">Coding Theory - II</a>	Richard W. Hamming, Naval Postgraduate School
21 April 1995	<a href="#">Error Correcting Codes</a>	Richard W. Hamming, Naval Postgraduate School
25 April 1995	<a href="#">Information Theory</a>	Richard W. Hamming, Naval Postgraduate School
27 April 1995	<a href="#">Digital Filters - I</a>	Richard W. Hamming, Naval Postgraduate School
28 April 1995	<a href="#">Digital Filters - II</a>	Richard W. Hamming, Naval Postgraduate School
2 May 1995	<a href="#">Digital Filters - III</a>	Richard W. Hamming, Naval Postgraduate School
4 May 1995	<a href="#">Digital Filters - IV</a>	Richard W. Hamming, Naval Postgraduate School
5 May 1995	<a href="#">Simulation - I</a>	Richard W. Hamming, Naval Postgraduate School
9 May 1995	<a href="#">Simulation - II</a>	Richard W. Hamming, Naval Postgraduate School
11 May 1995	<a href="#">Simulation - III</a>	Richard W. Hamming, Naval Postgraduate School
12 May 1995	<a href="#">Fiber Optics</a>	Richard W. Hamming, Naval Postgraduate School

28 April 1995	<a href="#">Digital Filters - II</a>	Richard W. Hamming, Naval Postgraduate School
2 May 1995	<a href="#">Digital Filters - III</a>	Richard W. Hamming, Naval Postgraduate School
4 May 1995	<a href="#">Digital Filters - IV</a>	Richard W. Hamming, Naval Postgraduate School
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11 May 1995	<a href="#">Simulation - III</a>	Richard W. Hamming, Naval Postgraduate School
12 May 1995	<a href="#">Fiber Optics</a>	Richard W. Hamming, Naval Postgraduate School
16 May 1995	<a href="#">Computer Aided Instruction - CAI</a>	Richard W. Hamming, Naval Postgraduate School
18 May 1995	<a href="#">Mathematics</a>	Richard W. Hamming, Naval Postgraduate School
19 May 1995	<a href="#">Quantum Mechanics</a>	Richard W. Hamming, Naval Postgraduate School
23 May 1995	<a href="#">Creativity</a>	Richard W. Hamming, Naval Postgraduate School
25 May 1995	<a href="#">Experts</a>	Richard W. Hamming, Naval Postgraduate School
26 May 1995	<a href="#">Unreliable Data</a>	Richard W. Hamming, Naval Postgraduate School
30 May 1995	<a href="#">Systems Engineering</a>	Richard W. Hamming, Naval Postgraduate School
1 June 1995	<a href="#">You Get What You Measure</a>	Richard W. Hamming, Naval Postgraduate School
2 June 1995	<a href="#">How Do We Know What We Know</a>	Richard W. Hamming, Naval Postgraduate School
6 June 1995	<a href="#">You and Your Research</a>	Richard W. Hamming, Naval Postgraduate School





# Hamming on Hamming: Learning to Learn

Hamming: Learning to Learn

[paper](#) [speaker](#) slides: [.ppt](#) [.pdf](#)



*Presenter:*  
**Richard W. Hamming**

Naval Postgraduate  
School

*Presentation:*

[Superintendent's  
Guest Lecture \(SGL\)](#)

*Date:* 30 April 1990

**Richard W. Hamming**



**Learning to Learn**

**The Art of Doing Science and Engineering**

100%  
75%  
50%

Dr. Hamming's presentation to all students and faculty in the 1990 NPS Superintendent's Guest Lecture (SGL) provides a synopsis overview of many of the most fundamental ideas encountered in his career.

# Reflections on Los Alamos (Manhattan Project, World



## War II)

- Wartime call to service.
- “Janitor of science” and first computers.
- To perform great work, study the masters.
- No two histories of the time are consistent.
- Thoughts on the accuracy of the computed  $O^{18}$  radiative-absorption cross section for slow neutrons, considered on the day prior to the detonation of the first atomic device.

# **Namesake Concepts**

## **1**



**Hamming error-correcting codes:**

**Carefully added redundancy which allows automatic detection & correction of errors.**

- Hamming bits: redundancy built into hardware

**Forward error correction:**

**Sufficient redundancy that a receiver (on forward side) can correct errors without retransmission by original sender.**

# **Namesake Concepts**

## **2**



**Hamming distance:**

**The number of positions which differ when comparing corresponding bits between two code words.**

**Sometimes used as a measure of conceptual distance, rather than spatial or numerical distance.**

# **Namesake Concepts**

## **3**



**Hamming predictor-corrector (PC) set for ordinary differential equations:**

**One of numerous numerical-analysis techniques used to make computer computations accurate by damping out progressive roundoff errors.**

**Overcomes a fundamental limitation of discrete arithmetic processing implemented in computer systems.**

# **Namesake Concepts**

## **4**



### **Hamming digital filter**

**Application of digital techniques (discrete computer processing) to perform signal processing, historically possible only with analog electronic circuitry.**

# Richard W. Hamming



## Books Authored

- Numerical Methods for Scientists and Engineers
- Computers and Society
- Introduction for Applied Numerical Analysis
- Calculus and the Computer Revolution
- Digital Filters (3<sup>rd</sup> Edition, January 1989)
- The Art of Doing Science and Engineering, Learning to Learn

# Richard W. Hamming



## Papers Authored

- A Class of Integration Formulas
- The Computer as an Experimental Tool
- A Computer Scientist Looks at Statistics
- Error Detecting and Error Correcting Codes
- Impact of Computers
- Educational Implications of the Computer Revolution



# Richard W. Hamming



## Papers Authored

- Intellectual Implications of the Computer Revolution
- One Man's View of Computer Science
- Introduction to "Fundamental Theory of Servomechanisms"
- The Mechanization of Science
- A Note on the Location of the Binary Point in a Computing Machine

# Richard W. Hamming



## Papers Authored

- Nuclear Magnetic Resonance in Crystals
- Numerical Analysis vs. Mathematics
- Pitfalls in Numerical Analysis- IEEE Talk, March 19, 1968
- Numerical Evaluation of Electron Image Phase Contrast
- Stable Predictor-Corrector Methods for Ordinary Differential Equations

# Richard W. Hamming



## Papers Authored

- The Impact of Computer technology on Management Concepts, Planning, and Decision Making
- Checking Techniques for Digital Computers
- Social Implications of the Computer Revolution
- The Effects of Computers Upon Engineering Education

# Richard W. Hamming



## Papers Authored

- Mathematical Notes
- Controlling the Digital Computer
- Computer Appreciation Courses
- Convergent Monotone Series
- Monotone Series
- An Essay on Computer Science Training Programs
- The Transcendental Character of  $\cos x$

# Richard W. Hamming



## Papers Authored

- On the Distribution of Numbers
- Modern Control Theory
- A Class of Integration Formulas
- Computers and Society
- An Elementary Discussion of the Transcendental Nature of the Elementary Transcendental Functions
- Contributing to Modern Science and Engineering

# Richard W. Hamming



## Papers Authored

- Note on the Teaching of Trigonometry
- Effects of Computers Upon Engineering Education
- Electronic Digital Computer as an Intellectual Tool
- General Purpose System
- Standard for Computer Mathematics

# Richard W. Hamming



## Papers Authored

- Thinking Big Even with Small Computers
- Limitations of Computers
- A Philosophy of Computer Science of My Prejudices and Confusions
- How Do You Know the Simulation is Relevant?
- A History of Computing in the United States
- Fifth Generation Computers and Beyond

# Richard W. Hamming



## Papers Authored

- Invariance and Bertrands Paradox
- The Role of the Digital Computer in Scientific Research, Past, Present, and Future
- Gaussian Quadrature as a Minimization Principle
- Error Correcting Codes
- The Role of the Technical Societies in the Field of Computer Measurement



# Richard W. Hamming



## Papers Authored

- Statistical Estimation of Error Propagation Through Multiplication and Division
- A Systems Approach to Software Testing
- Noninterpolatory Quadrature Formulas
- The Frequency Approach to Numerical Analysis
- Compumetrics: The Way Ahead
- Computers and Computing in the '70's

# Richard W. Hamming



## Papers Authored

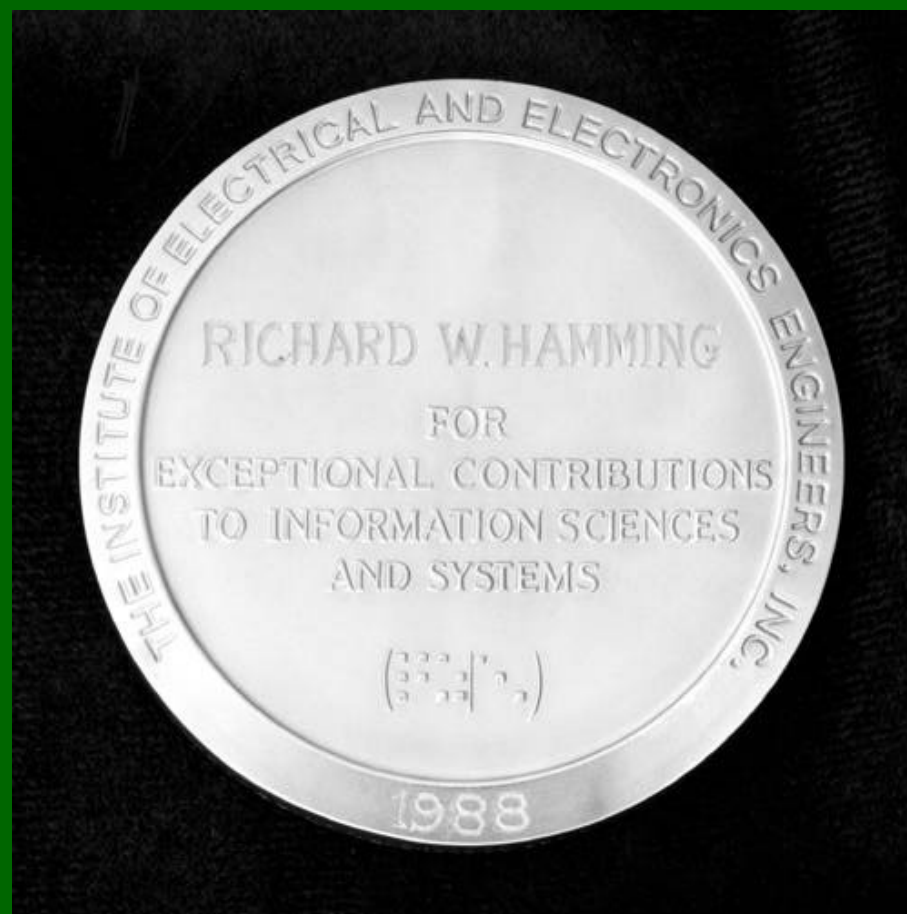
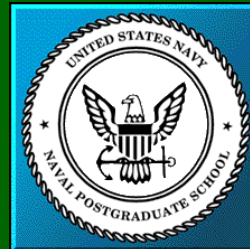
- Commencement Talk to Engineering School, University of California, Irvine
- The Distribution of Numbers- Applications
- The Distribution of Numbers- Mathematical Theory
- The Distribution of Numbers- Computer Theory
- The Distribution of Numbers- Physical Theory

# Richard W. Hamming



## Papers Authored

- Some Thoughts on Simulation
- Band Limited Functions
- Velocity Dependence on Contrast in Electron Images of Periodic Structures





# **Favorite quote**

**Luck favors the prepared mind.**

- Louis Pasteur, 1822-1895